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VOLUME III

FINAL REPORT

FOR

PLANNING ASSISTANCE FOR THE 30/20 GHZ PROGRAM

by G. Al-Kinani, M. Frankfort, D. Kaushal, R. Markham, C. Siperko and M. Wall

WESTERN UNION TELEGRAPH COMPANY

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Lewis Research Center

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16. Abstract

Volume III of this three volume Final Report contains contractor reports for Tasks 7 and 9. In Task 7, which includes the review of NASA generated Experiment Planning Document, defines the three basic experiment categories and consolidated experiments proposed by members of the Carrier Working Group by category and by carrier. The three experiment categories are: 1. Possible Service (PS); 2. Possible Service and Technology (PSAT); and 3. Possible Technology (PT).

Under Task 9 Western Union has provided review, recommendations and critique of the NASA generated Statement of Work (SOW) defining the technical requirements governing design, launch and operation of the 30/20 GHz experimental systems.

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TABLE OF CONTENTS

SECTION		PAGE
	EXECUTIVE SUMMARY	
1.0	Introduction	1
1.1	Task 7 - Summary	1
1.1.1	Objectives	1
1.1.2	Summary of Experiment Requirement Document Review	2
1.2	Task 9 - Summary	3
1.2.1	Objective	3
1.2.2	Summary of Demonstration System Requirements Document Review	3

ATTACHMENTS

TASK 7 REPORT - Planning Assistance for the 30/20 GHz Program; Development and Review of Experiment Program Plan

TASK 9 REPORT - Planning Assistance for the 30/20 GHz Program; Review and Critique of the Demonstration System Requirements Document

VOLUME III

EXECUTIVE SUMMARY

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1.0 INTRODUCTION

The Western Union Telegraph Company Government Systems Division (WUTCO-GSD) provided technical support to the NASA Lewis Research Center (LeRC) in accordance with the Statement of Work (SOW) requirements of the "Planning Assistance For The 30/20 GHz Program" contract awarded to WUTCO-GSD on May 1, 1980. Ten separate report tasks were defined in the SOW, some of which were amended during the course of the program. The task reports for Tasks 7 and 9 are contained in this volume.

Task 7 required Western Union to provide support to NASA LeRC for: preparation of the Experiment Planning Document; review and critique of the NASA generated 30/20 GHz Experiment Requirement Document to be incorporated in the RFP for the 30/20 GHz Experimental System.

Task 9 required Western Union to review and critique the Demonstration System Requirements Document and the preliminary RFP release for the 30/20 GHz Experimental System.

1.1 TASK 7 - SUMMARY

1.1.1 Objectives

The objectives of the Task 7 effort was to provide support to NASA LeRC for preparation of the Experiment Planning Document and the 30/20 GHz Experiment Requirement Document.

The Experiment Planning Document defines the three basic experiment categories and consolidated experiments proposed by members of the Carrier Working Group by category and by carrier. The three experiment categories are: Possible Service (PS), Possible Service and Technology (PSAT), and Possible Technology (PT). Western Union assisted NASA in preparation of the written material and formatting the proposed experiments by category and carrier. The

Experiment Planning Document is not included as a part of this final report since it was not a required Task output and was a NASA originated document.

Western Union's review and critique of the 30/20 GHz Experiment Requirements Document considered the experiments proposed by the carriers and by NASA, and the capabilities of the 30/20 GHz Experimental System design defined by NASA in the preliminary RFP.

1.1.2 Summary of Experiment Requirement Document Review

The intent of the Experiment Requirement Document (ERD), to be incorporated in the RFP for the 30/20 GHz Experimental System, is to identify the essential instrumentation and measurement capabilities to be incorporated in the space and ground segments of the experimental system. The instrumentation and measurement capabilities specified are those required to conduct the experiments proposed by the carriers and by NASA that are compatible with the experimental flight system design.

The ERD was initially reviewed considering the results of the Phase II contractors functional and technical conceptual design studies. This initial review produced several general comments, typical comments being: optimization schemes suggested in the ERD (i.e. adaptive compensation) have not been fully addressed in previous system concept studies; the impact on satellite cost, weight, and power produced by instrumentation and measurement assemblies was not addressed by any of the Phase II contractors other than TRW; switchable polarization for the trunking beam referred to in the ERD was proposed by only one of the five aerospace contractors, Ford Aerospace.

The ERD was then reviewed and comments, where applicable, were made on a paragraph by paragraph basis. In general the comments were oriented toward additional measurement, instrumentation, and control requirements that were deemed necessary to fully define system characteristics and performance in accordance with the intent of the experiments proposed. For example additional low noise amplifier measurements recommended included: output power: gain response and stability; in-band ripple; gain slope; LO phase noise; all of which affect system BER performance.

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Finally the proposed experiments were reviewed individually to: determine the adequacy of the measurement instrumentation specified to accomplish experiment measurement requirements; determine whether or not measurement instrumentation specified in excessive relative to experiment requirements; and finally to determine whether or not the proposed experiments can be accomplished with the experimental system design configuration to be flown. A total of seven proposed experiments were deleted from the ERD because of their incompatibility with the experimental flight systems design specified and four were deleted because they could more appropriately be accomplished by simulation.

The ERD reviewed is incorporated as an appendix to the Task 7 report so that the comments given in the report can be correlated with the corresponding ERD paragraph and the experiment matrix.

1.2 TASK 9 - SUMMARY

1.2.1 Objective

The objective of the Task 9 effort was to provide support to NASA LeRC for preparation of the Demonstration System Requirements Document by reviewing and commenting on iterations of the NASA generated document.

The Demonstration System Requirements Document defines the technical and performance requirements of the 30/20 GHz Experimental System.

1.2.2 Summary of Demonstration System Requirements Document Review

The intent of the Demonstration System Requirements Document (DSRD), to be incorporated in the RFP for the 30/20 GHz Experimental System, is to specify the proposed experimental system configuration, technical and performance requirements. Two iterations of the SDRD was reviewed relative to the results of the Phase II conceptual design studies. Western Union's perception of experimental system design requirements based on the results of the mix of services and traffic load forecasted in Western Union and UST&T market demand assessment studies, and on nominal system technical and performance criteria identified by the Carrier Working Group.

General conceptions and comments relative to the preliminary Demonstration System Requirements Document were: that it appeared to impose minimum requirements and did not strongly encourage bidders to propose alternatives with an increased scope of capabilities or to require use of new technology being developed under other NASA programs; further consideration of and analysis of assembly and system bandwidth requirements appear to be necessary; that additional emphasis should be placed on the system capability to reallocate transponder resources to accommodate traffic flow imbalances and peaks between beams; that a requirement for a steerable trunking beam and polarization switching should be considered to provide for beam isolation and cross polarization measurements.

The DSRD was further reviewed on a paragraph-by-paragraph basis and comments offered where appropriate in terms of Western Union's perception of experimental system requirements. Typical comments addressed: the need for additional system analysis, particularly under worst case propagation conditions and parking orbit slot; the system and assembly bandwidths in that they constrained the flexibility of the system, appeared to have inconsistencies, and should be increased to the maximum extent possible; other parameters at the system and assembly level that affected system performance and capabilities.

The final revision of Demonstration System Requirements Document reviewed is included as an appendix to the Task 9 report so that the review comments can be correlated with the system requirements specified.

NASA REPORT NO. 1-4-W-1-T7

TASK 7 REPORT
PLANNING ASSISTANCE FOR THE 30/20 GHZ PROGRAM DEVELOPMENT AND REVIEW OF EXPERIMENT PROGRAM PLAN

NASA Contract No. NAS3-22461 Task 7

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TABLE OF CONTENTS

SECTION		PAGE
1.0	Introduction	1
1.1	General Comments	1
2.0	Specific Comments	2
2.1	Measurement Requirements	2
2.2	Tracking, Telemetry and Command Requirements	3
2.3	Beacon Requirements	3
3.0	Master Control Station	4
3.1	Measurements Requirements	4
3.2	MCS and Data Reduction	4
4.0	Experimenter Ground Station	4

APPENDIX

A	Review and Critique - 30/20 Experimental Communications Satellite Experiments Requirements Document	A-1

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TASK REPORT 7
PLANNING ASSISTANCE TASK FOR 30/20 GHZ COMMUNICATION PROGRAM
NASA CONTRACT NAS3-22461, TASK 7

1.0 INTRODUCTION

Under the requirements of NASA Contract No. NAS3-22461, Task 7, Western Union was tasked to review and critique the 30/20 GHz Experiment Communication Satellite Experiment Requirement Document.

In general, the set of requirements for instrumentation and related systems satisfy the needs of all 30/20 GHz communications satellite experiments. The Table I 30/20 GHz Experiments Requirements Matrix is in agreement with the Experiment Planning Document with the exception of some minor changes.

1.1 GENERAL COMMENTS

Western Union's comments on the Table I Matrix and the instrumentation requirements are discussed for each item. The feasability of performing the experiments outlined in the Experiment Requirement Document and its impact on the system design was briefly discussed in Western Union's Task 3 report. Further comments will be included in Task 9 report entitled "30/20 GHz Experimental System." Western Union's general comments are as follows.

1. Certain optimization schemes, i.e., coding, link performance and adaptive margins are suggested in the experiment planning document. However, these analyses have not been addressed in the previous system concepts studies.

2. The impact of cost, weight and power requirements of the proposed instrumentation have not been addressed in the system concept studies as a function of the experiment capabilities of each design concept proposed.

3. Switchable polarization for trunking beam is referred to in the experiment planning document. However, with the

exception of the Ford antenna subsystem design no other aerospace contractor has proposed switchable polarization.

4. For certain parameters such as TDMA frame time, number of bits for burst identification, etc., the contractor should be given the option to propose alternative schemes for preamble bit structure.

2.0 SPECIFIC COMMENTS

2.1 MEASUREMENTS REQUIREMENTS

A. Fixed Beam Antenna Characteristics

No comments.

B. Scanning Beam Antenna Characteristics

No comments.

C. Low Noise Amplifiers

Measurements should include:

- Output Power
  Can be measured by the same instrument that measures the received signal level.
- Gain Response and Stability, inband ripple, gain slope.
- Gain measurement and resolution.
- L.O. phase noise is a critical impairment parameter and should be measured.

D. IF Switch

Settling time after switching should be measured. The effect of switching on signal impairments should be evaluated.

E. TWTA and Solid State Amplifiers

Input VSWR should be measured.

F. Baseband Processor

The demodulator performance is a critical factor for the link performance. The effect of demodulator caused impairments on the BER should be measured and evaluated. For the burst identification on the BER should be measured and evaluated. For the burst identification bits requirement, the contractor should be given the option of an optimum preamble design.

G. Satellite Attitude Control Data

No comments.

2.2 TRACKING, TELEMETRY AND COMMAND REQUIREMENTS

A. Data Transmission

No comments.

B. Command Equipment

Switching command for the various test instruments on the spacecraft should be added. Also redundancy switching for TT&C and status of the equipment should be included.

2.3 BEACON REQUIREMENTS

This should be included in Appendix B of the Requirements Documents.

3.0 MASTER CONTROL STATION

A. Since the earth station in the network encounter different propagation environment, the fundamental system parameters monitoring equipment should be place in the earth terminals. Data will be collected to support the experiments at the ground station, the satellite and the CCS. Selected data at the ground terminals will be collected continuously as part of remote control fault monitor subsystem. The data gathered by this subsystem will be available on request from the CCS over the system order wire. The data collected from monitoring instruments at the spacecraft will be downlinked to the CCS via the TT&C link. The data collection, analysis and storage system to summarize demonstration system performance will be contained in the CCS. The fundamental system parameters should be consistent with the design of the aerospace contractor.

B. Secondary System Parameter Monitoring

No comments.

3.1 MEASUREMENTS REQUIREMENTS

No comments.

3.2 MCS OPERATION AND DATA REDUCTION

Diversity Management applies to both uplink and downlink.

4.0 EXPERIMENTER GROUND STATION

Since the experimenter ground stations are supplied by the experimenters themselves, their instrumentation requirements, other than those required to operate within the 30/20 GHz system, should be their responsibility rather than a requirement imposed on NASA.

PS-1

Continuous CONUS coverage 30 and 20 GHz downlink beacons should be incorporated on the spacecraft and specified in Appendix B.

PS-2

A continuous 20 GHz digitally coded beacon signal should be transmitted from the spacecraft. The beacon should be specified in Appendix B.

PS-3

No comments.

PS-4

Continuous beacons at frequencies above 40 GHz should be incorporated in the spacecraft and specified in Appendix B, the 30/20 GHz Experimental System Requirements Document, if they are to be provided.

PS-8

No comments.

PS-9

No comments.

PS-10

No comments.

PS-11

No comments.

PS-12

No comments.

PS-13

Deleted from Table I.

PS-14

No comments.

PS-15

No comments.

PS-16

No comments.

PS-17

CPS mode measurements should be included in Table I in accordance with the Experiments Planning Document.

PS-18

CPS mode measurements should be included in Table I in accordance with Experiments Planning Document. Timing and synchronization measurements are not necessary to meet the objectives of this experiment.

PS-19

Could be conducted in conjunction with PS-17 using CPS earth stations in conjunction with existing long haul facilities.

PS-20, PS-21

These two experiments can be conducted by simulation, as it is impractical for direct demonstration systems experiment. Should be deleted for same reason as PS-22 and PS-23.

PS-22, PS-23

Deleted from Table I.

PS-24

No comments.

PS-25

This experiment requires portable terrestrial microwave equipment as do the other diversity experiment requirements.

PS-26

CPS mode parameters measurements should be included in Table I for this experiment.

PS-27

20 GHz and 30 GHz beacons should be incorporated in the spacecraft and specified in Appendix B of the Requirements Documents.

PS-28

No comments.

PS-29

Same comments as PS-27.

PS-30

No comments.

PS-31

Beacons at the frequencies 4, 6, 12, 14, 20, 30 GHz are required for this experiment. The beacons should be specified in Appendix B of the Requirements Documents.

PS-32

No comments.

PS-33

Same comments as PS-27.

PS-34

No comments.

PSAT-1

No comments.

PSAT-2

Implies CPS mode measurements by definition as opposed to trunking mode measurements as shown in Table 1.

PSAT-3

No comments.

PSAT-4

No comments.

PSAT-5

No comments.

PSAT-6

Deleted from Table I. Incompatible with system design concepts.

PSAT-7

CPS mode measurements should be included in this experiment since rain attentuation effects are more critical to CPS operation than to diversity trunking operation.

PSAT-8

No comments.

PSAT-9

Parameters to be measured should include timing and synchronization. Terrestrial interconnect link required.

PSAT-10

No comments.

PSAT-11

Horizontally and vertically polarized beacons should be incorporated in the spacecraft and specified in Appendix B.

PT-1

No comments.

PT-2

No comments.

PT-3

No comments.

PT-4

No comments.

PT-6

Deleted from Table I, not compatible with system design concepts.

PT7

No comments.

PT-9

No comments.

PT-11

No comments.

PT-12

No comments.

PT-13

Deleted from Table I, not compatible with 30/20 GHz program objectives.

PT-14

Same comments as PT-6.

PT-15

Deleted from Table I, antenna size not consistent with system design concepts.

PT-16

No comments.

PT-17

Same comments as PT-16.

PT-18

No comments.

PT-19

Basic requirements for this experiment related to propagation effects commented on previously.

PT-20

Link performance parameters to be measured should include LNA received signal strength, transmitted power and uplink BER in the spacecraft, and received signal strength, BER, transmitted power in the earth terminal.

PT-21

Trunking mode measurements should also be included in this experiment.

PT-22

Same comments as PT-6.

PT-23

No comments.

PT-24

No comments.

PT-25

This experiment requires the incorporation of C-band beacon in the spacecraft. Provisions for this beacon should be made in Appendix B of the Requirements Documents.

PT-26

This should be conducted by the contractor as part of the acceptance test.

PT-27

No comments.

PT-28

No comments.

APPENDIX A

APPENDIX A
30/20 GHZ EXPERIMENTAL COMMUNICATION SATELLITE
EXPERIMENTS DOCUMENT

A.1 INTRODUCTION

This Appendix contains the Experiments Document reviewed by Western Union in accordance with Technical Direction No. 2 of the NASA Contract NAS3-22451.

National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio
44135

NASA

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JUL 22 1981

Reply to Attn of: 6221

Western Union Telegraph Company
Government Systems Division
Attn: C. Siperko
7916 Westpark Drive
McLean, Virginia 22102

Subject: Contract NAS3-22461, Technical Direction No. 2

In accordance with paragraph 2.7 (Task 7) and pursuant to Article VII, Technical Direction, and within the total cost estimate set forth in Article VI, Estimated Cost, of this contract, Western Union is hereby directed to review and critique the attached 30/20 GHz Experimental Communications Satellite Experiments Requirements Document.

Dale E. Pope
Technical Manager

Enclosure

July 1, 1981

30/20 GHz EXPERIMENTAL COMMUNICATIONS SATELLITE

o EXPERIMENTS REQUIREMENTS

1. INTRODUCTION

The purpose of these experiments requirements is to identify an integrated set of requirements for instrumentation and related systems that will satisfy the needs of all the 30/20 GHz communications satellite experiments. These experiments requirements are derived from a review of the Experiments Planning Document (EPD) dated June 1980, and documents made available by the NASA Phase I and II 30/20 GHz communications satellite contractors.

Recent 30/20 GHz experimental system technical requirements have precluded a number of experiments in the EPD. The experiments that can be accommodated with the updated system requirements are examined herein.

The requirements for the candidate experiments differ considerably from those of simple repeater-type satellites. Unique system features for the 30/20 GHz satellite include the TDMA signal format, satellite switchable intermediate frequency (IF) and baseband signals, scanning antennas, forward error correction (FEC), and power adaptation to compensate for rain fades. Therefore, different approaches for monitoring the network parameters and new techniques to measure the signals are required.

The experiments requirements are divided into three categories: (1) satellite on-board requirements, (2) master control station requirements, and (3) requirements for the dedicated ground station which are to be procured by the experimenters. The experiments requirements are synopsized in Table I.

2. SATELLITE ON-BOARD REQUIREMENTS

It is recognized that equipment on board the satellite must be kept to a minimum to conserve power and weight but must also provide

sufficient data collection and other functions to achieve the experimental purposes. The general instrumentation requirements are outlined below for each major on-board communication component. In most cases, equipment required by the possible technology (PT) experiments to characterize the components for technology development is also required as basic inputs for possible ~~service~~ system (PS) and possible ~~service~~ system and technology (PSAT) experiments. There may also be additional opportunities to combine instrumentations to reduce complexity, e.g., the output measurement of one device could be the input measurement of another.

2.1 Measurement Requirements

A. Antenna characteristics monitoring for fixed-beam antennas.

1. Polarization monitor:

   (if switchable polarizations are implemented)

2. Pointing accuracy:

   ±0.01° EW, ±0.01° NS (direct measurement if possible)

3. Transmitter antenna mismatch:

   (to be derived from TWTA output port reflected power data)

4. Antenna switch status:

   NY/Houston, WDC/Tampa

B. Antenna characteristics monitoring for scanning beam.

1. Pointing accuracy:

   ±0.01° EW, ±0 0.01° NS (direct measurement if possible)

2. Pointing command status:

   Command data for beams 1 and 2, 5 bits per beam

3. Transmitter antenna mismatch:

   (to be derived from TWTA output port reflected power data)

4. Switching time:

   5-μsec range, 0.1-μsec resolution

C. Low noise amplifiers.

1. Noise figure measurement:

   6-dB range, 0.25-dB resolution

2. Received signal level:

   50-dB range, 0.25-dB resolution

3. Calibration method for (1) and (2) to maintain accuracy of 0.5 dB

D. IF switches.

1. Input signal level:

   10-dB range, 0.25-dB resolution

2. Output signal level:

   10-dB range, 0.25-dB resolution

3. IF switches interconnection configuration:

   6 bits to indicate interconnections

4. IF switches switching time:

   4- to 20-nsec range, 1-nsec resolution

E. Traveling wave tube amplifiers (TWTA) and solid-state amplifier (SSA).

1. Input power level:

   20-dB range, 0.25-dB resolution

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2. Output power level:

   20-dB range, 0.25-dB resolution

3. Output port reflected power:

   20-dB range, 0.25-dB resolution

4. D.C. voltage and current:

   ±10 volts from nominal, 0.1-volt resolution

   ±2 amps from nominal, 0.1-amp resolution

5. Temperature:

   TWT amplifier ±75°C from nominal, 1°C resolution

   Solid-state device junction temperature -50°C to +150°C from nominal, 1°C resolution

6. Multiple power mode switching time:

   10- to 100-μsec range, 1-μsec resolution

   Mode command status 2 bits

F. Baseband processor (BBP).

1. Bit error rate (BER) monitoring equipment for each up-link receiver for each transmission:

   10^{-2} to 10^{-6} range (4 decade), 6-bits resolution

   Burst Identification: 10 bits

2. Received signal level for each up-link transmitter:

   50-dB range, 0.5-dB resolution

   Burst Identification: 10 bits

3. Burst position relative to frame period:

   1- to 100-μsec range, 1-μsec resolution

   Burst Identification: 10 bits

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4. Carrier acquisition time:

   1- to 100-μsec range, 1-μsec resolution
   Burst Identification: 10 bits.

5. Carrier frequency:

   ±200 MHz from nominal, 0.1-MHz resolution

G. Satellite attitude control data.

Satellite position and pointing data will be available to support experimental data reduction and analysis.

2.2 TRACKING, Telemetry and Command Requirements

In addition to the instrumentation sensors needed to perform the measurements indicated above, a tracking, telemetry and command system is required. The system will perform the usual satellite operations, such as power management and system monitoring. Additionally, requirements will be placed on this system by the experiments.

A. Data transmission.

1. Data preprocessing and formatting of experiment data collected in the satellite.

2. RF link to central control station

   Ka band - primary link (separate from transponders)
   S band - backup link

3. Data rate of experiment data (TBD)

B. Command equipment control of the following functions.

1. CPS/Trunking selection

2. IF switch program

3. Antenna switching

4. BBP

5. TWT power

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6. FEC

7. Scanning antenna program

2.3 Beacon Requirements

A Beacon transmitter that continuously transmits is required for each of the following frequencies:

Frequency (GHz)	0.8	20 and 30	42	94
Power (watts)	2	2	1	0.5
Coverage	CONUS*	CONUS*	CONUS*	Eastern U.S
Modulation	Continuous	100 Mbps, pseudo random biphase	100 Mbps pseudo-random biphase	Continuous
Polarization	Linear	Orthognal Linear, switched at 1 KHz	Linear	Linear
Allowable Phase Noise**	0.1	0.5	1.0	2.0
Purpose	Mobil Service Multipath	20/30 rain fade effects	Future communi-cation satellites	Model veri-fication

*Continental United States.

**Integrated phase noise (10 Hz to 100 MHz) in rad RMS.

Each of these beacons shall be stable in amplitudes to 0.1 dB per hour. The power output level shall be monitored to 0.1 dB absolute.

3. ~~CENTRAL~~ MASTER CONTROL STATION EXPERIMENT REQUIREMENTS

The ~~Central~~ Master Control Station (~~CCS~~ MCS) performs the total system management and operation throughout the life of the spacecraft. During the experiment period, the ~~CCS~~ MCS controls the system configurations and resources to satisfy the experiment requirements. Functionally, the ~~CCS~~ MCS comprises (1) a master station with the capability of communicating with trunking and CPS stations, (2) a TT&C and command link to control the satellite and collect the data generated by the instrumentation described in the foregoing section, and (3) a data processing center for ~~analyzing~~ processing & distributing the experiment ~~results~~ data.

The experiment requirements input document June 1981 indicates that a broad spectrum of experiments is proposed. If all parameters of interest for the candidate experiments were to be separately instrumented and recorded, the requirements would be excessive. In order to constrain the total instrumentation requirements in a technically feasible and cost-effective manner, the system parameters are integrated below into two categories: (1) fundamental system measurements and (2) secondary measurements. The fundamental system measurements are basic data required by the majority of the candidate experiments and, therefore, are to be measured and recorded by the ~~CCS~~ MCS on a regular basis for input to all the experiments. The secondary system measurements are those data that can be derived either from the fundamental system measurements or by special instruments.

3.1 Measurement Requirements

A. Fundamental System Parameters Monitoring Equipment.

1. BER monitoring equipment for down-link signals:

   10^{-2} to 10^{-6} range (4 decade), 6-bits resolution
   Burst Identification: 10 bits.

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2. Noise power level:

   50° to 250°K range, 1°K resolution

3. Received burst signal level:

   50-dB range, 0.5-dB resolution

4. Burst position relative to frame period:

   1- to 100-μsec range, resolution ±1 clock period

5. Frame period:

   900- to 1100-μsec range, resolution ±1 clock period

6. Burst frequency:

   ±200-Mhz range, 0.1-MHz resolution

7. Beacon receiver:

   Attenuation - over all accuracy of 0.25 dB
   Depolarization
   Scintillation

B. Secondary System Parameter Monitoring or Data Reduction. (Further details to be supplied.)

1. Message error rate:
2. Channel capacity:
3. Power adaptation and site switchover:
4. Echo effects:
5. Time delay effects introduced by satellite:
6. System loading effects:
7. Interchannel interference:

3.2 Master Control STATION Operation and Data Reduction

In addition to the instrumentation sensors needed to perform the measurements indicated above, the control and processing equipment listed below is required.

A. Configuration Control and Monitoring Equipment.

Equipment and software to monitor the antennas, power amplifiers, IF switches, and BBP on the spacecraft, to monitor participating earth stations, and to provide automated responses in real time to rain fades by increasing power and introducing FEC.

B. Diversity Management.

Equipment and software to monitor the central station diversity terminal and to transfer to that station when the trunking terminal signal falls below that of the diversity terminal. This is to be accomplished without interrupting the data flow.

C. CPS Routing

To respond in real time to order wire service requests by assigning time slots and issuing routing commands to the BBP.

D. Data Processing Equipment.

1. Compute ephemeris time

2. Compute CPS and Trunking SS-TDMA schedule, dwell time, and system connections according to the experiment requirement

3. Real time data collection from the satellite and central station terminals

4. Off-line data collection for experiments of general interest

5. Data reduction ~~analysis~~ and central data archiving

4. EXPERIMENTER GROUND STATIONS

In addition to the general requirements for ground stations as mentioned above, the ground stations to be supplied by individual experimenters will contain specialized instrumentation to accomplish their specific required measurements. The major items of this equipment are (to be determined).

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TABLE I - 30/20 GHz EXPERIMENT REQUIREMENTS MATRIX

✓ = REQUIREMENT
● = BACKUP

EXPERIMENT NUMBER	MODE			SPACECRAFT: LINK PARAMETERS		SPACECRAFT: BASE BAND PROCESSOR				SPACECRAFT: OTHER LINK HARDWARE						Master CONTROL STATION: TERMINALS							MASTER CONTROL DATA REDUCTION					MASTER CONTROL SYSTEM OPERATION FUNCTIONS						SPECIAL EXPERIMENTER SUPPLIED TERMINAL CAPABILITIES OR REMARKS
	BEACON	CPS	TRUNKING	LNA RECEIVED SIGNAL	TRANSMITTED POWER	UPLINK BER	UPLINK TIMING	UPLINK ACQUISITION	UPLINK FREQUENCY	IF SWITCH PERFORMANCE	TWTA PERFORMANCE	SOLID STATE AMP PERFORMANCE	LNA PERFORMANCE	ANTENNA PERFORMANCE: FIXED	ANTENNA PERFORMANCE: SCANNING	RECEIVED SIGNAL	NOISE	BER	TIMING	BEACON RECEIVER	TRANSMITTED POWER	POLARIZATION	MESSAGE ERROR RATE	CHANNEL CAPACITY	SYSTEM LOADING	INTERCHANNEL INTERFERENCE	SYNCHRONIZATION	ON LINE DATA ARCHIVING	TRUNKING CONTROL IF SWITCH & ANTENNA PROGRAM	TRUNKING RAIN ATTENUATION ADAPTATION (POWER & DIVERSITY)	CPS SCAN PROGRAM AND MESSAGE ROUTING	CPS RAIN ATTENUATION ADAPTATION POWER AND FEC	OFF LINE DATA ARCHIVING	
PS-1	✓	●	●	●	●											●				✓	●	●						✓					✓	DATA USED BY MOST OTHER EXPERIMENTS MEASURED AT MOST TERMINALS
PS-2	✓	●	●	●	●	●										●		●		✓	●							✓					✓	DATA USED BY MOST OTHER EXPERIMENTS MEASURED AT MOST TERMINALS
PS-3		✓		✓	✓	✓									✓	✓		✓		✓	✓							✓					✓	DATA USED BY MOST OTHER EXPERIMENTS MEASURED AT MOST TERMINALS
PS-4	✓																			✓								✓					✓	MEASURED AT MANY TERMINALS
PS-6		✓	✓																										✓	✓	✓	✓		
PS-9			✓	✓	✓						✓			✓		✓	✓	✓			✓							✓	✓	✓				REQUIRES FDMA EQUIPMENT
PS-10			✓													✓	✓	✓	✓				✓				✓	✓	✓	✓				
PS-11		✓		✓	✓	✓	✓	✓	✓																			✓			✓	✓		
PS-12		✓																						✓	✓			✓			✓	✓		SIMULATE NORMAL AND EXTREME SYSTEM LOADING – EXCLUSIVE USE OF CPS
PS-14		✓	✓			✓	✓	✓	✓							✓	✓	✓	✓				✓				✓	✓	✓	✓	✓	✓		
PS-15			✓													✓		✓										✓	✓	✓				
PS-16			✓																										✓	✓				COMPARISON LINKS
PS-17			✓																										✓	✓				PORTABLE DIVERSITY TERMINAL
PS-18			✓													✓		✓	✓								✓	✓	✓	✓				INSIGHT DIVERSITY
PS-19			✓													✓		✓	✓								✓	✓	✓	✓				USE DIVERSITY
PS-20			✓													✓	✓	✓						✓	✓			✓	✓	✓				
PS-21		✓														✓	✓	✓						✓	✓			✓			✓	✓		EXCLUSIVE USE OF CPS
PS-24		✓	✓	✓	✓	✓	✓	✓								✓	✓	✓	✓				✓				✓	✓	✓	✓	✓	✓		
PS-25			✓													✓	✓	✓					✓					✓	✓	✓				MOVABLE DIVERSITY TERMINAL
PS-26			✓	✓	✓											✓	✓	✓					✓					✓	✓	✓				
PS-27		✓	✓	✓	✓	✓	✓									✓	✓	✓					✓					✓	✓	✓	✓	✓		
PS-28		✓														✓		✓						✓	✓			✓			✓	✓		ECHO EFFECTS
PS-29	✓	●	●	●	●											●	●	●		✓	●	●						✓					✓	SEE PS-1
PS-30		✓																													✓	✓		AVAILABILITY MONITOR AT CPS TERMINAL
PS-31	✓	●	●	●	●											●	●	●		✓	●	●						✓					✓	SEE PS-1
PS-32			✓													✓		✓										✓	✓	✓				
PS-33	✓																			✓								✓						SEE PS-1
PS-34		✓	✓																										✓	✓	✓	✓		
PSAT-1		✓																													✓	✓		AIRBORNE CPS TERMINAL
PSAT-2			✓																										✓	✓				SPREAD SPECTRUM MODEMS
PSAT-3		●	✓		✓						✓					✓	✓	✓			✓							✓	✓	✓	●	●		
PSAT-4		✓														✓	✓	✓													✓	✓		
PSAT-5		✓														✓	✓	✓													✓	✓		
PSAT-7			✓																										✓	✓				
PSAT-8		✓	✓													✓	✓	✓					✓		✓		✓	✓	✓	✓	✓	✓		
PSAT-9			✓													✓	✓	✓										✓	✓	✓				
PSAT-10		✓	✓		✓											✓	✓	✓										✓	✓	✓	✓	✓		
PSAT-11		✓	✓													✓	✓	✓				✓						✓	✓	✓	✓	✓		
PT-1		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						✓	✓	✓	✓	✓		
PT-2		✓	✓								✓																	✓						
PT-3		✓	✓											✓	✓													✓						
PT-4		✓	✓									✓																✓						
PT-7			✓							✓																		✓						
PT-8		✓				✓	✓	✓	✓							✓	✓	✓	✓								✓	✓			✓	✓		
PT-11		✓	✓													✓	✓	✓				✓				✓		✓	✓	✓	✓	✓		
PT-12		✓				✓	✓	✓	✓							✓	✓	✓										✓			✓	✓		
PT-16		✓				✓	✓	✓	✓							✓	✓	✓	✓								✓	✓			✓	✓		
PT-18		✓	✓	✓	✓	✓										✓	✓	✓			✓							✓	✓	✓	✓	✓		
PT-19		✓	✓													✓	✓	✓										✓	✓	✓	✓	✓		
PT-20		✓	✓											✓	✓													✓						
PT-21		✓													✓	✓	✓	✓								✓		✓			✓	✓		REQUIRES SATELLITE TO HAVE 2 SCANNING BEAMS OF SAME POLARIZATION
PT-23		✓	✓	✓	✓	✓										✓	✓							✓	✓			✓	✓	✓	✓	✓		
PT-24			✓								✓																	✓	✓					FDMA MODEMS
PT-25		✓	✓											✓	✓	✓	✓	✓										✓						ATTITUDE CONTROL INFORMATION
PT-26																																		PRELAUNCH CHECK OF SATELLITE SYSTEMS CF PT 27 PT 28
PT-27		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓													✓						POST LAUNCH CHECKOUT
[illegible]																																		[illegible] MONITORING SEE PT 1 PT 2 PT 3 PT 4 PT 8

NASA REPORT NO. 1-4-W-1-T9

TASK 9 REPORT
PLANNING ASSISTANCE FOR THE 30/20 GHZ PROGRAM
REVIEW AND CRITIQUE OF THE DEMONSTRATION SYSTEM REQUIREMENTS DOCUMENT

NASA Contract No. NAS3-22461 Task 9

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TABLE OF CONTENTS

SECTION		PAGE
1.0	General Comments	1
2.0	Specific Comments	2

APPENDIX

30/20 GHz Experimental System	A-1

TASK REPORT 9

1.0 GENERAL COMMENTS

The statement of work describes a minimal 30/20 GHz communication system. In general the statement of work imposes minimum requirements which can be easily construed as goals. There is no encouragement to bidders to propose alternative or optional extensions to the statement of work. For example, specifying data rates, exclusion of FDMA for trunking, lack of cross-connectivity between the CPS and trunking subsystems, simultaneous CPS and trunking operation. Appendix A of this Task 9 report contains the technical requirements of the 30/20 GHz Experimental System provided by NASA to Western Union for review.

NASA is currently funding technology development programs for various communication subsystem POC assemblies. The SOW does not stress utilization of the hardware under development. Their use should be required unless a contractor can show that his recommended alternatives offer performance and cost advantages.

The bandwidth requirements specified for the LNA, IF switch matrix, antenna and power amplifiers is inconsistent with that specified in the respective technology program SOWs. The bandwidth specified for the above assemblies is 500 MHz (except for the TWTA). All of these assemblies are in series in the trunking transponder configuration. IF the contractor's design is limited to 500 MHz, the overall transponder bandwidth can be expected to be less than 500 MHz due to bandwidth shrinkage. Additionally, the useable bandwidth for TDMA operation would normally be constrained to something of the order of 80% of the channel bandwidth required for the transmission rates to be used. The implications are that the frequency plan could be constrained to a single frequency or two frequency plans with some overlap as a consequence of overall bandwidth limitations. Since the downlink transmission rates of the CPS and trunking channels are the same, resulting in the same channel bandwidth requirements, and the CPS beams will overlap trunking beams. The bandwidth limitations, therefore, could possibly preclude the potential for simultaneous CPS/trunking operation, and CPS/trunking interconnectivity. Furthermore, Washington, DC and New York

beams can possibly interfere with each other as a result of channel overlap. It is suggested that the specified bandwidths be re-evaluated so that the overall system bandwidth might be on the order of 30% of 2.5 GHz (750 MHz) or at least adequate for a non-overlapping two channel frequency plan.

The SOW does not explicitly address demonstration of transponder resource allocation to accommodate traffic flow imbalance between beams and traffic flow peaks. Similarly, reconfiguration of the IF switch matrix routing sequence specified as 2.0 microseconds is not clear. In reconfiguring the switch connectivity sequencing and reallocating resources (increasing/decreasing number of burst slot assignments) program changes in the on-board switch controller and in earth station controllers should occur within a guard time slot to avoid losing synchronization and to insure that the IF switch and earth station reconfiguration and burst slot assignment changes occur simultaneously. The limit on the overall sequence of events could be specified as 2.0 microseconds for clarity, but with no loss of timing and synchronization.

The SOW has no provision for beam isolation or cross polarization isolation measurements for the trunking system. The SOW, therefore, should consider one steerable beam and a beam with polarization switching capability.

2.0 SPECIFIC COMMENTS

Paragraph 3.0.h (1) - No comment.

Paragraph 3.0.h (2) - Let the contractor provide data relative to his design capability.

Paragraph 3.0.h (3) - Because of bandwidth shrinkage, the bandwidth requirements for TDMA transmission and useable bandwidth within a channel, potential interference problems are possible between Washington, DC and New York beams.

Paragraph 3.0.h (4) - This is a key objective of the system and is understood.

Paragraph 3.0.h (5)	-	This paragraph constrains the system to SS-TDMA. Alternate design should be encouraged to incorporate FDMA access as well as SS-TDMA to provide the system with more flexibility as a development test bed.
Paragraph 3.0.h (6)	-	Should specify a minimum burst rate of 240 MBPS. MSPS should read MBPS.
Paragraph 3.0.h (7)	-	General Comments.
Paragraph 3.0.h (8)	-	Range of power control should be identified after design analysis to determine total margin and diversity gain necessary to satisfy availability requirements. The validity of margin numbers relative to rain attenuation characteristics for all rain zones at various levels of availability is still questionable. If availability is not a criterion for the test bed demonstration system, these numbers are acceptable.
Paragraph 3.0.h (9)	-	No comment.
Paragraph 3.0.h (10)	-	No comment.
Paragraph 3.0.h (11)	-	No comment.
Paragraph 3.0.i (1)	-	No comment.
Paragraph 3.0.i (2)	-	Identify the number of CPS stations as a minimum and let the contractor determine capabilities of his proposed system beyond the minimum.
Paragraph 3.0.i (3)	-	Why identify a limit. Less than ten (six, for example) could be accomplished in one beam

dwell location and is, therefore, not very meaningful. The address coding is all that needs to be changed for broadcast (multi-destination) reception.

Paragraph 3.0.i (4)	-	No comment.
Paragraph 3.0.i (5)	-	The ability to provide either open or closed loop synchronization capabilities must be compatible with baseband processor capabilities. The contractor should identify design changes required in the baseband processor.
Paragraph 3.0.i (6)	-	No comment.
Paragraph 3.0.i (7)	-	No comment.
Paragraph 3.0.i (8)	-	MSPS should read MBPS.
Paragraph 3.0.i (9)	-	No mention is made of power control. As noted previously in the comments in Paragraph 3.0.h (8), the validity of the margin numbers are questionable and the comments given there apply.
Paragraph 3.0.i (10)	-	Same as 3.0.h (9). The contractor should develop a strawman model to estimate the maximum number of stations expected to require adaptive link margin augmentation.
Paragraph 3.0.i (11)	-	MSPS should read MBPS.
Paragraph 3.0.i (12)	-	MSPS should read MBPS.
Paragraph 3.0.i (13)	-	No comment.

Paragraph 3.1 (a)	-	Specifying satellite location at 100° west longitude is the optimum location. Since extension of this system to an operational network is an important requirement of 30/20 GHz system, the contractor should provide analysis for locating the satellite at the extreme locations of the orbital arc. The scan losses, rain margins and availability are directly affected by the satellite location.
Paragraph 3.1 (b)	-	No comment.
Paragraph 3.1 (c)	-	No comment.
Paragraph 3.1 (d)	-	No comment.
Paragraph 3.1 (e)	-	No comment.
Paragraph 3.1 (f)	-	No comment.
Paragraph 3.1.1	-	The performance characteristics of the advanced technology hardware should be consistent with the applicable assemblies being developed under the technology development program and emphasis placed on their use. Alternative designs proposed by the contractor should be justified on the basis of improved performance and cost reduction.
Paragraph 3.1.1 (b)	-	The contractor should submit a test plan that includes the description of the proposed instrumentation required for various experiments detailed in Appendix C. The impact on cost, weight and power on the flight system should be addressed. It should be noted that the experimental plan refers to, for example, switchable

polarization, various coding schemes for optimum performance whereas no mention of this is made in the system design concept.

Paragraph 3.1.1 (c)	-	No comment.
Paragraph 3.1.1.1 (a)	-	Recomment antenna minimum bandwidth 1.5 GHz and 2.5 GHz as target. Furthermore, antenna bandwidth of 500 MHz is not consistent with Paragraph 3.0.h (3) where the bandwidth specified is 0.3 x 2.5 = 750 MHz.
Paragraph 3.1.1.1 (b) (c)	-	The maximum dimension of the reflector as restricted by the launch vehicle should be specified. The minimum gains required should be specified taking into consideration scan losses for satellite location at the extreme end of the useable orbital arc.
Paragraph 3.1.1.1 (d) (e)	-	No comment.
Paragraph 3.1.1.1 (f)	-	No comment.
Paragraph 3.1.1.2 (a)	-	Cross-connectivity between CPS and trunking should be considered.
Paragraph 3.1.1.2 (b)	-	See General Comments.
Paragraph 3.1.1.2 (c)	-	The bandwidth should be consistent with the IF Switch matrix being developed, where the switch bandwidth is 2.5 GHz.
Paragraph 3.1.1.2 (d)	-	Switching plus settling time of the IF switch should be addressed and these considered with respect to guard times, unique word length requirements, etc.

Paragraph 3.1.1.3	-	Specify requirements for baseband processor consistent with technology development SOW.
Paragraph 3.1.1.4 (a)	-	No comment.
Paragraph 3.1.1.4 (b)	-	No comment.
Paragraph 3.1.1.4 (c)	-	Since the TWTA will be operating in high power mode less than 0.01% of the time, increasing the efficiency at lower power level may reduce the prime power requirement if it is feasible.
Paragraph 3.1.1.4 (b)	-	750 MHz bandwidth is not consistent with the bandwidths specified in the technology program SOW.
Paragraph 3.1.1.5 (a)	-	No comment.
Paragraph 3.1.1.5 (b)	-	No comment.
Paragraph 3.1.1.5 (c)	-	Bandwidth is not consistent with TWTA to which SSPA serves as a backup and also is not consistent with technology development program SOW.
Paragraph 3.1.1.6 (a)	-	1200°K appears to be too high. With LNA noise figure specified as less than 5 db, total noise contribution should be approximately 900°K.
Paragraph 3.1.1.6 (b)	-	No comment.

APPENDIX A

APPENDIX A

30/20 GHZ EXPERIMENTAL SYSTEM

A.1 INTRODUCTION

This appendix contains the technical requirements for the 30/20 GHz Experimental System provided by NASA. Western Union reviewed this document as part of Contract NAS3-22461 under Task 9.

1.0 Introduction

This document presents the technical requirements for the 30/20 GHz Experimental System. The requirements define the 30/20 GHz Experimental System that will be developed to verify the advanced technology required to enable orbit and spectrum conservative implementation of satellite communications in the 30/20 GHz frequency band. The advanced technology employed in the 30/20 GHz Experimental System must be scaleable to operational system requirements defined herein.

2.0 Definitions and Abbreviations

2.1 Definitions

Experimental System: The flight system, the NASA trunking station, the NASA customer premises services station, the Master Control Station, and any other NASA ground equipment necessary for operating the flight system (i.e., ranging station).

Flight System: The spacecraft bus and communications payload.

Spacecraft Bus: The part of the flight system which includes the following subsystems: electrical power; attitude control; reaction control; propulsion; thermal control; structure; telemetry, tracking, and command; and any others required to support the communications payload.

Communications Payload: The part of the flight system which performs the communications and RF beacon functions and contains the required technology for flight verification.

Space Transportation System: The Space Shuttle (orbiter, external tanks, solid rocket booster, and flight kits), upper stage, and any associated flight hardware and software excluding the apogee motor.

Master Control Station (MCS): The station which performs all functions associated with the control and operation of the flight system, NASA Ground Station System, and experimenter stations. The MCS also provides monitoring and/or control of the STS upper stage.

NASA Ground Station System: The NASA trunking station, the NASA CPS station, and any other necessary ground equipment required under the Execution phase contract.

NASA Trunking Station: The primary terminal, a diversity terminal, and the associated interconnect, with capability for providing communications using the fixed beams or the scanning beams.

NASA CPS Station: The NASA transportable station which provides only the low burst rate communications using the scanning beams.

Experimenter Stations: The trunking, CPS, and other stations to be provided by the experimenters.

2.2 Abbreviations

BER:	bit error rate
BBP:	baseband processor
CONUS:	contiguous United States
CPS:	Customer Premises Services
C/I:	carrier to interference ratio
db:	decibel
dbm:	decibels referenced to a milliwatt
EIRP:	effective isotropic radiative power
FDM:	frequency division multiplexed
FEC:	forward error correction
Gbps:	gigabits per second
GHz:	gigahertz
G/T:	antenna subsystem gain/total received system noise temperature

IF:	intermediate frequency
Kbps:	kilobits per second
KHz:	kilohertz
Mbps:	megabits per second
MCS:	Master Control Station
MHz:	megahertz
Msps:	megasymbols per second
RF:	radio frequency
SSPA:	solid state power amplifier
SS-TDMA:	satellite switched - time division multiple access
STS:	Space Transportation System
TDM:	time division multiplexed
TDMA:	time division multiple access
TT&C:	telemetry, tracking, and command
TWT:	traveling wave tube
TWTA:	traveling wave tube amplifier

3.0 30/20 GHz Experimental System

a. The Experimental System shall consist of the flight system, the NASA ground station system, and the Master Control Station.

b. The Experimental System shall operate within the 27.5 to 30.0 GHz band on the uplink and within the 17.7 to 20.2 GHz band on the downlink.

c. The Experimental System shall be capable of providing (1) communications using the fixed beams between the NASA trunking station plus five experimenter trunking stations; (2) communications using the scanning beams between the NASA trunking station, the NASA CPS station, plus forty experimenter CPS stations; and (3) support of RF beacon experiments. Items (1) and (2) are not required to be simultaneous.

d. The Experimental System shall provide the capability to conduct the experiments defined in Appendix C, Experiment Requirements Document, and to satisfy the project requirements defined in Appendix A, Mission Need Statement.

e. The Experimental System shall be designed to operate for four years.

f. Provision for trunking communications, CPS communications, and RF beacon operations during eclipse shall be limited to that required for evaluation of the thermal performance of the antenna subsystem.

g. Communications is not required for a ground station during the time the sun, flight system, and ground station are in alignment.

h. The Experimental System shall meet the following trunking requirements:

(1) Interconnectivity and coverage shall be provided simultaneously for up to four nodes within a network of six nodes. A node is defined as one or more trunking stations located within the same beam. Stations operating at the same frequency but in different beams shall be no closer than two antenna beamwidths. The final beam locations (to be located within CONUS) will be specified by NASA on or before the Execution phase contract preliminary design review.

For the System Definition Study, the six nodes shall be assumed to be Cleveland; Los Angeles; New York; Washington, D.C.; Houston; and Tampa. Simultaneous communications shall be provided between Cleveland; Los Angeles; New York or Houston; and Washington, D.C. or Tampa (Figure 1).

(2) Within the active four node trunking network, six trunking stations shall be capable of being operated on a TDMA basis.

Provisions shall be made for accommodating three trunking stations per beam.

(3) For the System Definition Study, the trunking beams shall use the same frequency spectrum except for the Washington, D.C. beam which shall use an adjacent frequency spectrum. In order to demonstrate spectrum conservation, the total spectrum utilized shall be less than 30 per cent of the 2.5 GHz allocated bandwidth.

(4) Interconnection of the communications trunking network shall be accomplished via the flight system.

(5) Access method shall be TDMA; routing shall be SS-TDMA.

(6) The uplink and downlink burst rates shall be fixed and shall be within the range 240 Msps $\pm$ 10 per cent. The throughput capacity of each trunking beam including the overhead shall be a minimum of 240 Mbps $\pm$ 10 per cent.

(7) The Experimental System shall contain all controls and associated equipment to provide the capability to operate all trunking channels over the entire output power range of both the uplink and the downlink. Power control shall be managed from the MCS and shall be automatic.

(8) The end-to-end bit error rate on all trunking links shall be maintained at less than 10^{-6} through the use of power control. The power control shall automatically (without operator intervention) accommodate uplink rain fades of up to 18 db and/or downlink rain fades of up to 8 db whenever the rain fade rate is less than 1 db per second (rain fade rate to be updated at System Definition Study contract award). Forward error correction coding to improve rain degraded links shall not be utilized.

(9) The trunking system shall be designed to have at least 90 per cent probability of providing trunking communications after the initial on-orbit operational date as follows:

(a) Between any six beam locations with four active channels for 0 to 2 years.

(b) Between any four beam locations with three active channels for 2 to 4 years.

Note: This probability will be updated at System Definition Study contract award.

(10) Any trunking station shall be assigned participation into or removal from the trunking network only through the MCS.

(11) The Experimental System shall be designed to provide communications between trunking ground stations having an antenna diameter of five meters.

i. The Experimental System shall provide CPS services that meet the following requirements:

(1) Coverage shall be provided simultaneously by two, independent flight system scanning beams. Each beam shall serve a contiguous sector and a portion of six nodes within CONUS (Figure 1). Each contiguous sector shall be contiguous to each other for a minimum of three beamwidths. The CPS coverage will be finalized by NASA on or before the Execution phase contract preliminary design review. For the System Definition Study it shall be assumed that the total contiguous sector coverage area shall include New York, Washington, D.C.; Atlanta; Chicago; and Cleveland. The six nodes shall be at Denver, San Francisco, Seattle, Dallas, Omaha, and Phoenix.

(2) Thirty CPS stations shall be capable of operation within one scan period of each scanning beam. Provisions shall be made for accommodating six CPS stations per beam dwell location. It shall be assumed that 75 per cent of the stations in a scanning beam area are low burst rate stations and 25 per cent are medium burst rate stations.

(3) The CPS system shall provide interconnectivity among all CPS stations on a circuit-switched basis with a minimum equivalent circuit capacity of one voice channel (64 Kbps). The CPS system shall also provide the capability to distribute CPS traffic on a one station-to-several stations (less than 10) basis.

(4) Communications among the CPS stations shall be conducted on a FDM/TDMA basis through the use of a scanning multi-beam antenna and a baseband processor on board the flight system (refer to Section 3.1.1.3 for definition of baseband processor). Multiple accessing in the CPS network shall be conducted under control of the MCS according to a reservation scheme.

(5) Synchronization of the CPS network is to be accomplished through a closed loop mode of operation. The capability to conduct open loop synchronization experiments shall be included.

(6) The BBP shall be controlled through the MCS.

(7) The frequency plan for each of the two scanning beams shall be identical. Isolation between beams shall be provided through the combined use of orthogonal polarization and spatial separation.

(8) The CPS uplink for each beam shall consist of the following types: (1) Four fixed burst rate FDM channels within the range 30 Msps ± 10 per cent; and (2) one fixed burst rate channel within the range 120 Msps ± 10 per cent. Both types of uplinks

shall not be provided simultaneously, for the case when both scanning beams are operating. For the case when only one scanning beam is operating, the capability shall exist to provide both uplink types simultaneously. The system shall be capable of switching between uplink types within a beam dwell. The total throughput capacity of the CPS system without FEC and including overhead shall be a minimum of 240 Mbps ± 10 per cent. The downlink in each beam shall be a single fixed burst rate channel within the range 240 Mbps ± 10 per cent.

(9) The Experimental System shall nominally operate with an end-to-end BER of less than 10^{-6} in clear weather with margins of 5 db on the uplink and 3 db on the downlink exclusive of any margin available with FEC and data rate reduction. The total margin with FEC and data rate reduction shall be at least 15 db on the uplink and at least 13 db on the downlink to provide 10 db rain fade margin.

(10) FEC with data rate reduction shall be applied automatically to rain-degraded uplinks and/or downlinks in order to maintain the BER at 10^{-6}. The total BBP uplink and downlink data rate FEC capacity shall be a minimum of 12.6 Mbps

(11) The CPS system shall be designed to have at least a 90 per cent probability of providing CPS communications after the initial on-orbit operational date as follows:

a) Two scanning beams at full total data and FEC throughput capacity for 0 to 2 years.

b) A minimum of one 120 Mbps ± 10 per cent and four 30 Mbps ± 10 per cent burst rate channels shall be functional for 2 to 4 years to provide a total throughput capacity of at least 120 Mbps.

240 120 Mbps

Note: This probability will be updated at System Definition Study contract award.

(12) The Experimental System shall be designed to provide CPS capability to ground stations having an antenna diameter of three meters for the 30 Mbps ± 10 per cent burst rate uplink channels and five meters for the 120 Mbps ± 10 per cent burst rate uplink channels.

(13) As a backup mode, both CPS scanning beams shall be capable of simultaneous routing through the IF switch.

(14) Any CPS station shall be assigned participation into or removal from the CPS network only through the MCS.

3.1 Flight System

a. For the System Definition Study, the flight system shall be assumed to be located in geostationary orbit at 100° West longitude. The final orbit location will be specified on or before the Execution phase contract preliminary design review.

b. The desired orbit location of the flight system shall be maintained to within ± 0.05° in both the North-South and East-West directions for the mission duration.

c. The flight system shall be designed for an on-orbit life of four years.

d. The flight system shall be launched by the Space Transportation System.

e. The flight system shall be monitored and controlled through a Ka-band TT&C subsystem from the time of on-orbit checkout through the four years of operation.

f. The flight system shall be monitored and controlled through a non-Ka-band TT&C subsystem from separation from the Space Shuttle through checkout at the on-orbit location. This subsystem shall also serve as a backup to the Ka-band TT&C subsystem for on-orbit operations.

3.1.1 Communications Payload

a. The advanced technology components defined in subsequent sections shall be incorporated in the communications payload to provide as a minimum the services defined in 3.0.

b. Instrumentation shall be provided to the experiments in Appendix C to be evaluated.

c. A CONUS beacon system with polarization modulation shall be provided to allow investigation of propagation phenomena at the current experimental frequencies of 20 and 30 GHz and for future satellite service at 40 and 50 GHz. The nominal EIRP, using a solid state source, for each beacon frequency shall be 45 dbm. The nominal polarization modulation rate shall be 1 KHz. The operation of the system for each beacon frequency shall be controlled by the MCS.

3.1.1.1 Antenna

a. The antenna subsystem shall provide a minimum dynamic bandwidth of 500 MHz per beam within the uplink operating frequency range of 27.5 to 30.0 GHz and the downlink operating frequency range of 17.7 to 20.2 GHz.

b. The antenna reflector providing the downlink beam shall have a minimum diameter of three meters and the uplink antenna reflector shall have a minimum diameter of two meters. A single reflector may be employed for both the uplink and downlink.

c. The antenna subsystem shall provide a downlink minimum gain of 50 db for each fixed beam, and a downlink minimum gain of 47 db for each CPS station within the two scanning beam areas. The antenna subsystem shall provide an uplink minimum gain of 54 db for each fixed beam, and an uplink minimum gain of 51 db for each CPS station within the two scanning beam areas. This gain specification does not include pointing losses due to spacecraft attitude control and station keeping errors. However, losses due to all beam forming networks shall be included.

d. The antenna subsystem shall provide both uplink and downlink beam isolation of at least 30 db each between any two trunking beams whose beam centers are at least two beam widths apart.

e. The antenna subsystem shall provide both uplink and downlink beam isolation of at least 30 db whenever the scanning beam centers are two beam widths apart. The MCS shall be capable of producing a minimum of two beam width separation between the two scanning beams.

f. The scanning beam switching speed shall be a maximum of 1 microsecond.

3.1.1.2 IF Matrix Switch

a. The IF matrix switch shall provide as a minimum four inputs and outputs with internal redundancy.

b. The IF matrix switch shall be capable of cycling through a fixed routing configuration of the four active trunking stations. (A routing configuration is the sequence of input to output connections, within a fixed routing period.) The IF switch shall be capable of changing from one routing configuration to another within two microseconds.

c. The channel bandwidth for one input to output path shall be 500 MHz minimum.

d. The switching time required to change an input to output connection shall be less than 20 nanoseconds. Isolation, between the wanted and unwanted signals at the switched output port, shall be 30 db within 30 nanoseconds of switch initiation.

3.1.1.3 Baseband Processor

The BBP shall provide the interconnect for the CPS system. Functions to be included in the BBP shall be frequency demultiplexing of the uplink channels, demodulation of each of the uplink channels on a TDMA basis, automatic (without opeator intervention) and selective (to those stations suffering rain fade) forward error correction (FEC) decoding on the uplink and encoding on the downlink, digital routing

of the bit streams, and reformatting and remodulating to a single downlink burst rate.

3.1.1.4 Traveling Wave Tube Amplifier

a. The TWTA (which includes the power supply and associated controls) shall be designed using a multimode (variable beam current) TWT.

b. The TWTA's shall be capable of providing 8 watts of RF power in the low power mode and at least 40 watts of RF power in the high power mode. In order to compensate for rain attenuation, the RF power shall be capable of being continuously varied over the range of 8 to 40 watts without output power disruption.

c. The efficiency (RF power out/dc input power) of the TWTA's shall be a minimum of 20 percent in the low power mode and a minimum of 35 percent in the high power mode.

d. The TWTA shall provide a minimum bandwidth of 750 MHz.

3.1.1.5 Solid State Power Amplifiers

a. The communications payload shall include at least two SSPA's of the identical type and design.

b. The SSPA's shall be capable of providing a minimum of 8 watts of RF output power.

c. The SSPA's shall have a minimum bandwidth of 500 MHz.

3.1.1.6 Low Noise Receiver Circuit

a. The input circuit for any beam shall provide a system noise temperature, from all sources, not to exceed 1200°K.

b. The input circuit shall have a minimum bandwidth of 500 MHz within the range of 27.5 to 30.0 GHz.

3.1.2 Payload Technology Scaleability Requirements

It is necessary that the technologies embodied in the Experimental System be representative of, and scaleable to, operational requirements. The experimental technology requirements shall therefore establish the technology base from which operational technology requirements will only be an engineering extension. Thus, the scaling of the Experimental System to an operational system shall only involve changes in engineering design and shall not require a change in concept and/or technology. The technology requirements for operational systems as defined in this document shall include the Experimental System requirements in this Appendix plus the following extensions to that technology:

(a) Antenna - The Experimental System antenna design shall be scaleable to an operational design that would provide twenty 0.3 degree beamwidth spot beams, and six scanning beams that would provide full CONUS coverage.

(b) IF Matrix Switch - The Experimental System matrix switch design shall be scaleable to an operational design that provides a matrix size of input and output ports of at least 20 x 20 and has provisions to accommodate as a minimum any five matrix cross-point failures.

(c) Baseband Processor (BBP) - The Experimental System BBP design shall be scaleable to an operational design that would provide interconnectivity between at least six scanning beams which cover CONUS; provide a total system throughput of at least 3 Gbps; route traffic with circuit capabilities ranging from 64 Kbps up to the maximum channel burst rate; provide, on demand, automatic and selective FEC coding and rate gain to individual users; provide closed loop synchronization; and provide a 90 per cent probability of a total capacity at the end of ten years of operation of no less than 2.5 Gbps. Interconnection of fixed and scanning beams through the baseband processor is not required.

3.2 NASA Ground Station System

3.2.1 NASA Trunking Station

a. The trunking station shall consist of a primary terminal, a diversity terminal and the associated terrestrial interconnect link.

b. The trunking station shall provide the 240 Msps ± 10 per cent burst rate trunking capability. In addition, the trunking station shall provide both the 30 Msps ± 10 per cent and 120 Msps ± 10 per cent burst rate CPS capabilities. The station shall also provide the RF communications link for the MCS.

c. The diversity terminal shall be separated from the primary terminal by at least 16 kilometers.

d. The primary and diversity terminal antennas shall be five meters in diameter and have a minimum G/T of 29 db. Tracking capability and environmental control shall be provided.

e. The primary trunking terminal shall include the following seven (7) major subsystems: 1) Antenna, 2) RF Section, 3) Modems, 4) User Interface Equipment, 5) Controller, 6) Control and Display, and 7) Terrestrial Interconnect Equipment.

f. The diversity terminal shall include the following three major subsystems: 1) Antenna, 2) RF Section, and 3) Terrestrial Interconnect Equipment.

g. Both the primary and diversity terminals shall have an RF loop-back system for functional terminal checkout.

h. Shelter shall be provided for the equipment.

i. The diversity terminal shall not require attendant personnel.

3.2.2 NASA Customer Premises Service Station

a. The CPS station shall provide the 30 Msps $\pm$ 10 per cent burst rate CPS capability.

b. The CPS station antenna shall be three meters in diameter and have a minimum G/T of 25 db. A steptrack system shall be provided.

c. The CPS station shall be transportable on a trailer. The total height and width of the vehicle including the

reflector shall not exceed 3.7 meters and 2.4 meters respectively in the transportable configuration.

d. The trailer shall be designed to include an enclosure for all station equipment except the antenna and shall allow CPS operation directly from the trailer.

e. All station equipment shall be designed for standard 120 volt AC power. Auxiliary power shall not be included in the station design. Power will be supplied from an adjacent facility source.

f. The CPS station shall include the following six major subsystems: 1) Antenna, 2) RF section, 3) Modem, 4) Controller, 5) User Interface Equipment, and 6) Control and Display.

g. The CPS station shall be capable of operation in both scanning beam polarizations by a simple orthogonal adjustment of the antenna feed systems.

h. The CPS station shall provide the capability for automatic and selective FEC encoding and decoding for recovering link performance during rain fades.

i. The CPS station shall have an RF loop-back capability for functional terminal checkout.

j. The CPS station shall require no more than two persons to set up and check out. Environmental control shall be provided as necessary for equipment. Once in operation this station shall not require attendant personnel.

3.2.3 Other NASA Equipment

Other equipment such as ranging and beacon transmitting stations required to operate the flight system shall be provided.

3.3 Master Control Station

a. The Master Control Station (MCS) shall provide and perform all functions associated with the on-orbit control and operation of the flight system (mission operations), with the control and operation of the communications network (network operations), and with the conduct of the experiments.

b. Functions to be provided for mission operations shall include monitoring and/or control of the flight system; tracking and ranging; orbit determination; ephemeris determinations; range delay computations; flight system maneuver planning and execution; and pre-launch, launch, and post-launch support through on-orbit verification of the flight system.

c. Functions to be provided for network operations shall include control of user access and traffic, signal and payload monitoring, maintenance of link quality under varying weather conditions through power augmentation and FEC coding control, scanning beam control, BBP control, and IF matrix switch control.

d. Functions to be provided for experiment operations shall include the collecting, formatting, recording, and archiving of data associated with the service and technology experiments. In addition, processing capability shall be provided for the advanced technology components.

e. For trunking services, transmission burst assignments shall be made on an off-line basis. For CPS, beam dwell times shall be made off-line, however the allocation of the beam dwell time among the CPS stations in any beam location shall be dynamically assigned.

f. Capability shall be provided at the MCS to control the flight system through both the Ka-band TT&C subsystem and to invoke the use of the backup TT&C subsystem.

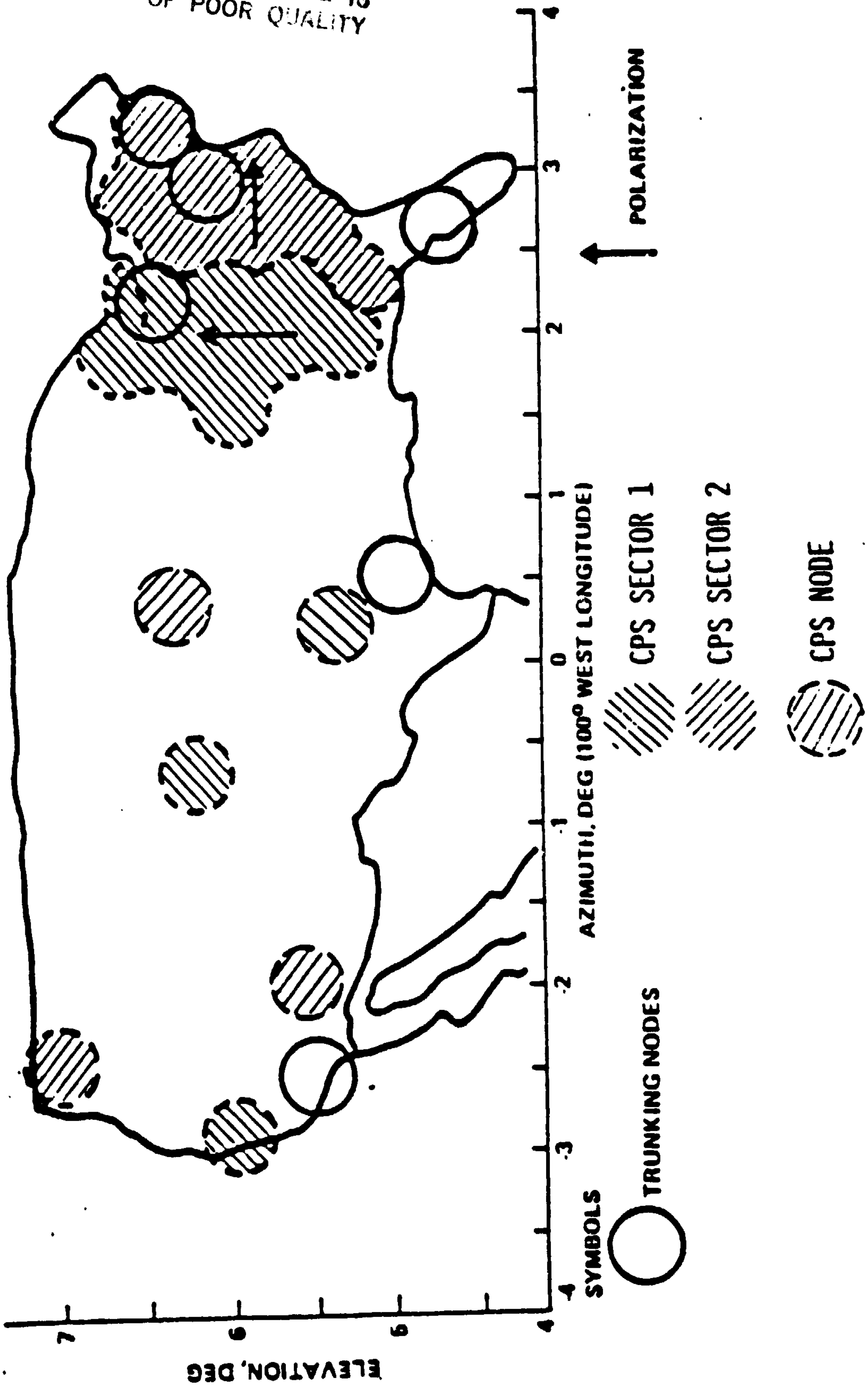

FIGURE 1 - COVERAGE REQUIREMENTS